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AIDS FOR IMPROVING VISION IN WHITE-OUT

by

C. L. Schlichting, S. M. Luria, J. A. S. Kinney,
D. F. Neri, S. W. Kindness
and
H. M. Paulson

Naval Medical Research and Development Command
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R. A. Margulies, CDR, MC, USN
Commanding Officer
Naval Submarine Medical Research Laboratory

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C. L. Schlichting, Ph.D.
S. M. Luria, Ph.D.
J. A. S. Kinney, Ph.D.
D. F. Neri, B. A.
S. W. Kindness, HM3, USN
H. M. Paulson, B. A.

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SUMMARY PAGE

THE PROBLEM

To measure the effectiveness of two different optical aids under conditions of uniform visual stimulation (white-out).

FINDINGS

The wearing of yellow goggles improved the perception of depth contours in both low light and snowy conditions. The lenses designed to correct for the nearsightedness (myopia) induced by a featureless visual field did not improve the perception of visual targets.

APPLICATION

There is a strong suggestion that the use of yellow goggles will improve the perception of depth under the conditions of uniform visual stimulation found in winter military operations. More research is needed, however, to specify more precisely the conditions under which yellow goggles will prove useful and the reason for the failure of the lenses to improve vision.

ADMINISTRATIVE INFORMATION

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ABSTRACT

The ability to see well deteriorates markedly under conditions of uniform visual stimulation (white-out). These conditions are frequently encountered by both the Navy and Marine Corps troups operating in winter environments. This study tested two different visual aids in an attempt to improve vision under these conditions. One of the aids, a yellow goggle, showed promise for improving the perception of depth in both low light and snowy conditions. The other, a correction for empty-field myopia (nearsightedness induced by a featureless visual field) did not improve vision. Further research is planned to specify more precisely the conditions in which the yellow goggles improve vision, and to investigate the reasons for the failure of the lenticular corrections to improve vision

INTRODUCTION

Both the U. S. Navy and the Marine Corps must be adequately prepared and equipped to perform in all kinds of hostile environments. A major problem hindering military operations in the cold regions of the world is poor visibility caused by weather conditions. These include fogs (sea fog, land fog, and ice fog), snow and blowing snow, and "white-out". The latter term is used to describe any of the above weather conditions, but in a strict sense it refers to the situation in which the visual scene is completely and uniformly white, due to multiple reflections between the snow-covered terrain and a low cloud cover. The particular weather condition most frequently encountered depends upon the part of the world involved; sea fogs obviously occur in coastal regions, snow is more or less prevalent in different areas, and the true white-out is almost strictly a polar phenomenon.

The physics of these white-out situations is well understood.[1] As a rough rule of thumb, loss of visibility in fog, snow, smoke, or under water occurs when the contrast between an object and its background is reduced to less than 2 per cent. Loss of contrast is due to scatter and absorption by particles in the air through which the light rays are transmitted; these particles are of many types, but in white-outs they consist of water, in the form of droplets, ice crystals, or snow flakes, or of salt particles over the ocean. The size of these particles varies greatly, but all can reduce contrast to less than 2%. The smallest particles differentially absorb light of different colors, while the largest absorb uniformly across the spectrum. The loss of contrast can be calculated from the distance and particle size, and visibility ranges can thus be predicted; nomographs for such predictions are indeed available for a number of environmental conditions.[2]

The uniform stimulation produced in the arctic regions is likewise well understood. When there is little in the environment except fields of snow and low cloud cover, the light is reflected back and forth until the distribution from all angles is uniform; in fact, physical measurements

of the light in a full 360 degrees around an individual reveal no differences whatsoever.[3]

The effects of all the different types of white-outs are, to the eye, the same in that visual stimulation throughout the visual field is nearly uniform. This situation has a common and profound physiological effect: vision is lost. Considerable research has been done in the laboratory using different techniques for producing uniform visual fields: stabilized visual images, diffuse materials over the eyes, or uniform lighting conditions (the visual Ganzfeld). The results all agree that changing stimulation is essential for vision; without it objects quickly disappear from view in a matter of seconds.[4,5]

A related visual problem occurs when individuals find themselves on snow-covered ground on overcast days, such that there is flat lighting and no shadows. Under these conditions, they have great difficulty detecting undulations in the terrain or seeing other low-contrast targets in the snow .

Attempts to deal with these problems have a long history. During World War II and shortly thereafter, a special subcommittee of the Armed Forces-NRC Vision Committee was established to work on visibility problems. Much of our current information on atmospheric optics stems from their efforts.[6] These previous attempts have been summarized by Harker[7] in a bibliographical survey of whiteout, which discusses the physical, physiological, and psychological factors involved.

Since the time of Harker's summary, interest in white-out has dimmed, and there is little current literature dealing with solutions to the problem. At the same time, however, knowledge of the basic physiology of the visual system has increased rapidly and has suggested a number of approaches to the problem of improving vision under these

conditions. Several such approaches have been tried under laboratory conditions,[8-10] and the two most promising were further tested in field trials with the Marines at the Mountain Warfare Training Center, Pickel Meadow, California.

Experiment I evaluated one possible aid under flat lighting conditions, the wearing of yellow goggles. Experiment II evaluated the possibility of using corrective lenses to overcome the myopia induced by "white-out" conditions.

EXPERIMENT I

Depth Perception with Yellow Goggles

Many skiers and hunters report that they see better with yellow goggles under conditions of uniform visual stimulation. Scientific research, however, has been unable to substantiate the effect. Many comparisons, using primarily acuity as the measure, have failed to show any advantage in wearing yellow goggles.[11-13] New physiological research, however, suggests a theory which might explain the inconsistency;[14-16] basically, this theory states that daytime vision is mediated by two separate neural systems that deal with different types of visual information. One of these, the chromatic system, is involved in the perception of color and deals with information from the color receptors (the cones) in an antagonistic or subtractive manner. The blue-yellow and red-green opponent processes are a result of this antagonistic system.

The other system, the achromatic system, does not code neural information on the basis of color. In this system the output of the different types of color receptors are all additive; the response to a particular stimulus can be predicted by the sum of the responding neurons.

A number of different characteristics of the visual system can be explained by this difference in additivity between the two neural systems. It has become increasingly apparent that some visual processes are mediated solely by the achromatic system. Flicker photometry is an example of this type of process.[17] Other processes such as color discrimination under controlled light conditions may be mediated solely by the chromatic system. Finally there are many instances of visual processes that engage both types of neural systems. The perception of the brightness of lights composed of mixed colors is an example of this circumstance.

For many visual functions, however, the relative contribution of each of the two systems remains to be determined. A related area still to be adequately explained is the subjective improvement in vision attributed to yellow goggles. The findings relative to the chromatic and achromatic systems may be the key to the yellow-goggle effect. While acuity seems to be mediated by the achromatic system it may be that the yellow-goggle effect is a product of the chromatic system and that the yellow filter is somehow removing an inhibitory effect in the opponent-color process. This loss of inhibition could result in a larger neural signal and hence enhanced subjective vision.

We know that acuity is not the visual function improved by yellow goggles. The current study was therefore designed to determine whether depth perception might be a function that is enhanced by wearing yellow goggles, since preliminary studies in the Naval Submarine Medical Research Laboratory suggested that this might, indeed, be the case.[10]

METHOD

Subjects: Subjects were Marine Corps enlisted men and officers. A total of 42 males participated as subjects. They ranged in age from 17 to 35 years. All subjects who required visual correction wore their glasses under the goggles while observing.

Targets: A series of holes was dug in the snow in two geographically separate areas. Each area provided a flat expanse of snow of at least 150 feet in each direction. Each hole was approximately 36" in diameter and ranged in depth from 2" to 15". In each location there was one shallow hole and one deep hole. The other holes were intermediate in depth. There were four holes at location A and five holes at location B. They were all dug so that they were separated laterally by at least two yards and were all the same distance from each observation point. Altitude of the experimental areas was approximately 8,600 ft; the snow cover was approximately two feet.

Goggles: Previous laboratory studies had shown no differences in responses between the use of yellow goggles and no goggles.[10] Since weather conditions encountered in winter operations generally necessitate the use of some type of device to protect the eyes against wind and blowing snow, the decision was made to compare only the yellow goggles and a neutral filter. The actual transmissions were chosen to take into account the type of terrain and lighting conditions in which problems with depth perception are usually reported.

One pair of the matched set was a standard yellow goggle designed for skiers. These employed a sharp cut-off yellow filter transmitting essentially nothing below 500 nm and more than 80% of the light above 580 nm. Overall light transmission through these goggles was 60%. The other pair of goggles was comprised of a pair of neutral density filters matched to transmit the same amount of light as the yellow goggles. Transmission in these goggles was equal across the visible spectrum.

Procedure: Each subject observed with both the yellow goggles and the matched neutral density goggles. Each subject observed with one type of goggle in one location then the other type of goggle in the other location. At each location the type of goggle first administered to each

successive subject was alternated. One half the subjects observed first at location A and the other half observed first at location B. Only one subject at a time observed at each location.

After the purpose and nature of the experiment was explained to the subject, he was given the appropriate set of goggles, instructed to stand on a marker 150 feet in distance from the holes, and then asked if he saw any holes. If he answered "Yes", he was then asked how many and to judge which was the deepest and which was the shallowest. If the subject was not correct in judging the number of holes and the shallowest and deepest, he was moved to another marker ten feet closer to the holes and the questions were repeated. The subject continued to move closer in ten-foot increments until he could correctly judge the total number of holes and the shallowest and deepest. The procedure was then repeated at the other location with the other goggle type.

Responses in two observation conditions were studied. In one, observations began late in the afternoon as soon as the sun had disappeared behind the mountains (i.e., low, flat light) and continued until just before darkness. There was no precipitation during any of these four sessions and no shadows were visible. Thirty-four subjects observed under these conditions. In the second condition, eight additional subjects observed one morning during heavy falling and blowing snow. Unfortunately the stimulus holes rapidly filled with snow and further observations could not be obtained.

After the subjects had completed their judgments in both locations - most were given a questionnaire to fill out. The questionnaire was designed to ascertain which goggles each subject preferred under the observation conditions. Because each marine had previously been issued a pair of standard military sunglasses these were included on the questionnaire.

RESULTS

Figures 1 and 2 show the distance from the holes at which the total number of holes was correctly judged and also the distance at which the subjects were able to correctly judge which hole was the shallowest and which hole was the deepest. Figure 1 shows the results of the observations made by the first group of 34 subjects in the flat light of late afternoon. Under these conditions, for both types of judgments, the yellow goggles enabled the subjects to make a correct judgment more than six feet farther from the holes than when observing with the neutral density goggles. Due to variability in the data neither difference was significant at the .05 level on a t-test (to judge number of holes, t= .815, df = 59; to correctly judge depth, t = .892, df = 59).

Figure 2 shows the results of eight different subjects who observed one morning at the same locations during a snow storm. Under these conditions subjects were able to correctly judge both the number and depth of the holes at a farther distance than in the late afternoon conditions. For both types of judgments the yellow goggles again yielded superior performance. In the case of the depth judgment the difference amounted to 22 feet; the difference to correctly judge the number of holes was 12 feet. Both of these differences were significant beyond the .05 level on a t-test (to judge number of holes, t = 2.18, df =7, $p < .05$; to judge depth, t = 2.94, df = 7, $p < .05$).

Results of the questionnaire showed that almost 70% of the subjects felt that the yellow goggles were better than the neutral goggles of equal transmittance or than the standard military sunglasses that they had been issued. Table 1 shows the exact breakdown of the goggle preferences reported.

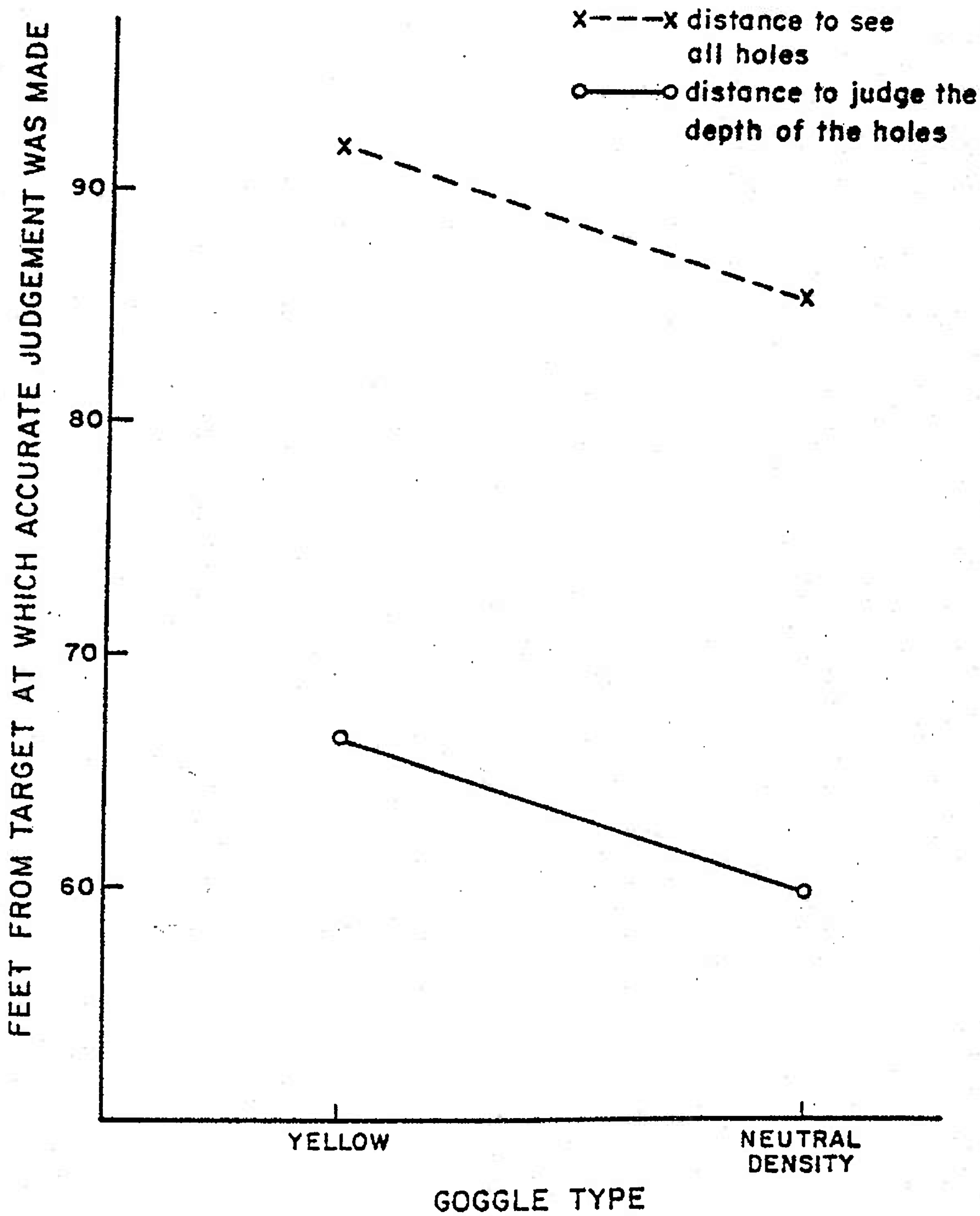

Fig. 1. Distance from the holes to correctly judge the number of holes and to correctly judge the shallowest and the deepest hole: late afternoon conditions.

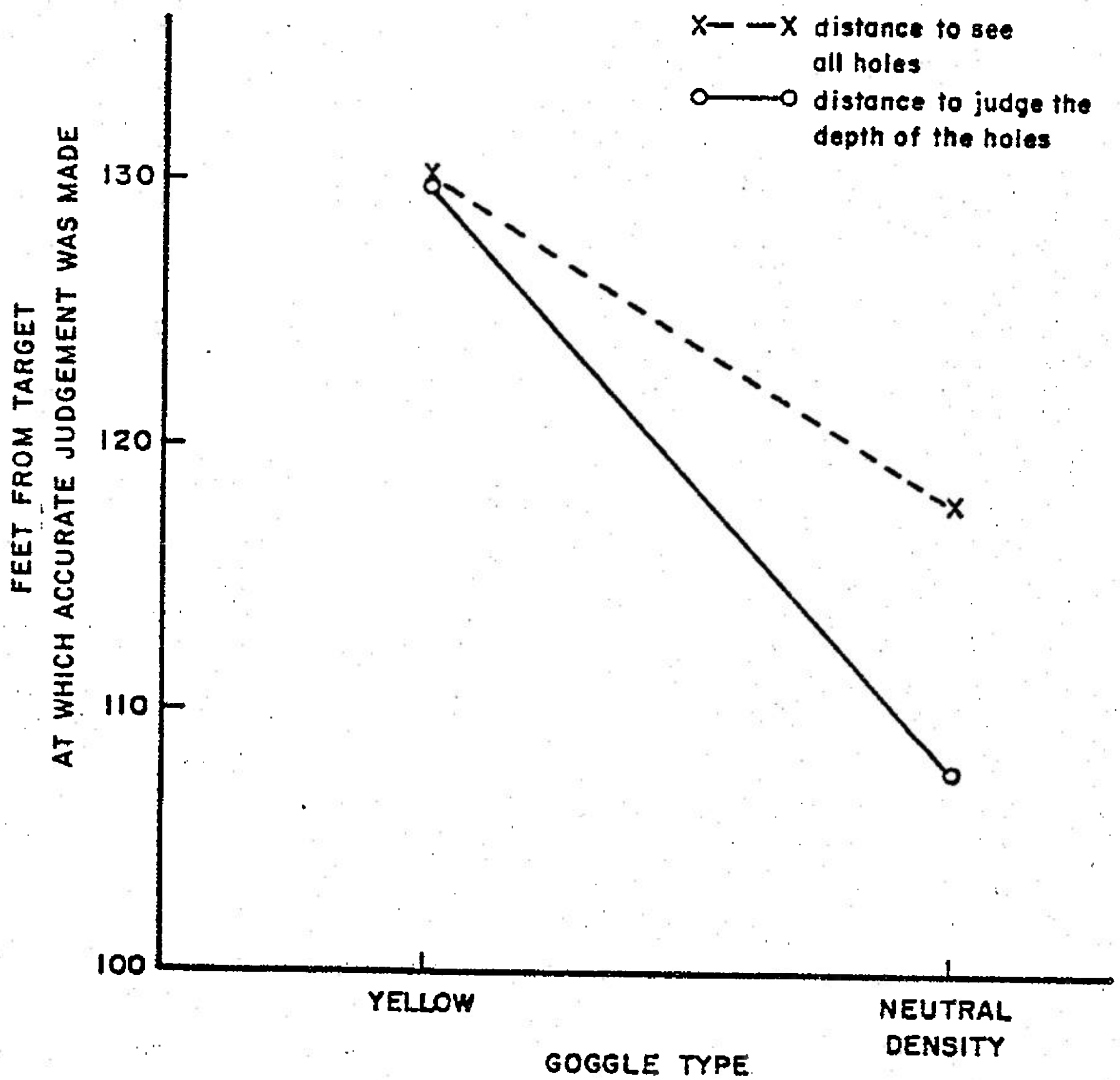

Fig. 2. Distance from holes to correctly judge the number of holes and to correctly judge the shallowest and the deepest hole: heavy blowing snow conditions (morning)

Table 1. Subjects' responses to question: "Which type of glasses gives you the best vision?"

Goggle type	Preference N	%
Yellow	23	69.7
Neutral Density	9	27.3
Standard military issue (gray)	1	3.0
	33	

DISCUSSION

Under both flat light and snowy conditions, the wearing of yellow goggles improved the perception of depth relative to the wearing of matched neutral density filters. Under the flat lighting conditions (late afternoon) there was an average improvement of 7% in the ability of the subjects to see the correct number of holes and an improvement of 11% in their judgment of the depth of the depressions. Under the snowy condition the improvement amounted to 20%. We thus believe that yellow goggles are effective in improving depth perception, but that many more subjects will be needed to prove this under the highly variable conditions encountered in field experiments. This question will be pursued in future experiments.

This finding is of practical importance to individuals who must operate effectively under low contrast visual conditions, but many important questions concerning the effect remain to be answered. One is the mechanism by which depth perception is improved.

Another, of particular practical importance, is the question of the range of light levels over which yellow goggles are effective. The

outdoor illumination used in these experiments was fairly low, either attenuated by snow or the sun having disappeared behind mountains. Since these are the conditions under which skiers prefer yellow goggles, an optimum range is suggested.

Further research is currently planned with a larger subject population and under varying conditions in order to better determine the conditions under which the goggles prove useful.

EXPERIMENT II

Correction for Empty-Field Myopia

It has long been known that when viewing a bright, empty field, the eye is typically not focused for infinity but rather for some intermediate distance.[18-20] This condition is known as "empty-field myopia"; implying of course that the ability to detect distant targets is impaired. Although this is a problem of considerable practical concern, attempts to correct it have unfortunately not been very successful.

It is now known that one reason for the failures is that the magnitude of empty-field myopia varies markedly for different individuals,[21,22] and, until recently, it was impossible to predict the degree of myopia that a given individual would exhibit. The recent development of the laser optometer, however, makes it an easy matter to measure.[23] Since the precise magnitude of myopia can be determined, it should be possible to successfully correct it.

Empty-field myopia presumably is an important contributing factor to the difficulty in seeing during the condition known as "white-out." Because of the lack of objects to look at, the eye becomes myopic;

as a result, the ability to see distant objects, which ordinarily would be visible, is lost. Several studies have shown that it is possible to correct for empty-field myopia in the laboratory.[8,24-26] In this experiment, we have tried to determine whether or not visual performance in the field can be improved under conditions which should lead to empty-field myopia.

METHOD

Location: The experiments were carried out at the Marine Mountain Warfare Training Center in January, 1980. The goal was to obtain a completely uniform, white visual field of view. To this end, the most suitable terrain available was chosen. The subject stood in a snow-covered field and looked towards a snow-covered hill which served as a background. There were, however, some rocks and shrubs visible through the snow in various places on the hill despite the rapidly falling and blowing snow during the time the experiment was carried out. Since these conditions did not constitute a "white-out", the subjects were instructed to make their observations through a 6 mm hole in a sheet of white paper held against the face. The effect of this was to eliminate the view of the extraneous objects and the experimenter when the subject was looking at the target.

Subjects: Two groups of subjects were tested. One group consisted of staff members of the Naval Submarine Medical Research Laboratory who were at the Training Center to conduct a variety of experiments. Twenty laboratory personnel were scheduled to go to the Training Center. Prior to departure, they were examined with the laser optometer and appropriate spectacle corrections were prepared for their use. Of these 20, only five were available for the experiment.

The other group was composed of 25 enlisted men in the U. S. Marine Corps who were there for winter survival training. They could not be examined with the optometer, and the magnitude of their myopia was unknown. They were tested with two arbitrary lenticular corrections, -1.5 and -2.5 D.

Targets: Targets were painted on stakes which were 0.5 m long and 1.27 cm (.5 in) square in cross section. The stakes were painted white to reduce their visibility in the snow. They were driven perpendicularly into the snow so that only the top 30 cm or so protruded above the surface. The tip of each stake was either left white or painted light gray, or had a thin, black circle 1 cm in diameter with a break in the circle of about 3 mm at either 0, 90, 180, or 270°. The contrast of the gray tips, calculated using the formula $L_W - L_g / L_W$ where L_W is the luminance of the white paint and L_g is the luminance of the gray paint, was .18. The gray tips were seen, of course, primarily against a background of snow rather than the white stem of the stake. At 5000 feet new snow reflects 90% of the incident light, more than does the white paint. (For this reason, the stakes themselves looked gray against the snow.) The contrast of the gray tips against the snow was .24.

Procedure: The Marine subjects observed in groups of six, with two experimenters each noting the responses of three men. Each group of subjects participated in three blocks of trials at each observation distance. In each subgroup of three men, one subject first wore glasses containing plano lenses, one wore the -1.5 D correction, and the third man wore the -2.5 D correction. A series of 8 judgments of the color of the tip of the stake was made while wearing these lenses. The subjects then switched lenses and made 8 more judgments at the same distance. The lenses were then switched a third time, and 8 more judgments were made. All judgments at the 55 m distance were made before moving to the 37 m position.

After each judgment, the subjects turned their backs to the stake while the experiment placed a new stake in the same spot. The subjects were then told "Ready" and they turned to face the stake while holding a sheet of white paper with a 6 mm hole in it in front of their eyes. The subjects were instructed to view the stakes through this hole using their preferred eye. Each subject then made a judgment and whispered his response to the experimenter. When all subjects had responded, they again turned their backs while the experimenter placed the next stake in position.

Six additional Marines also observed the broken circle targets at a distance of 12 m. The same lenses and procedure were used as with the gray and white targets.

Laboratory subjects were tested using the same procedure, except that only the plano lenses and the pre-determined correction for each subject was used. The gray and white tipped targets were used.

RESULTS

Laboratory personnel

Performance at a distance of 37 m was close to perfect both with and without corrective lenses. Results, therefore, are given only for the test distance of 55 m (180 ft). Table 1 shows that the performance of two of the five subjects was improved by correction, and the performance of three subjects was degraded. The mean percent of correct target identifications was 46 with no correction and 42 with the corrections. These means are not significantly different, according to the Wilcoxon Matched-Pairs Signed-Ranks Test.

Table 1. Percent correct identification of gray and white targets at 55 m by laboratory personnel with plano and corrective lenses

Subject	Plano	Correction
DG	.88	.62
EH	.12	.88
EN	.25	.50
CS	.38	.12
GW	.50	.38
Mean	.46	.42

It was discovered subsequently, however, that one of the subjects whose performance was improved by the correction (EH) was myopic by about half a diopter. This subject had observed in many experiments in recent years, had been given a standard refraction several times, and had been emmetropic until recently. Her marked improvement in this experiment was obviously due more to her general need for some distance correction than to empty-field myopia.

Marines

The percentages of correct identifications of the gray and white targets at a distance of both 37 and 55 m when the subjects were wearing plano lenses and the -1.5 D and -2.5 D corrections are given in Table 2. At the nearer distance, the subjects correctly identified a total of 157 targets with plano lenses, 78.5% of the total possible. While wearing -2.5 D lenses, they identified only 137 targets, or 68% of the total. Of the 25 subjects, only 11 exhibited an improvement in performance with either correction; the performance of 11 suffered with

Table 2. Percent correct identification of gray and white targets at 37 and 55 m by Marines with plano and corrective lenses

Distance	Plano	-1.5 D	-2.5 D
37 m	78.5	77.5	68
55 m	62	53	46

the lenses, and that of three subjects remained perfect throughout. The effect of the lenses was not significant, according to a Friedman non-parametric analysis of variance ($X^2 = 2.34$, $p < .40$).

At a distance of 55 m, the Marines identified a total of 123 targets correctly without a corrective lens - 62% of the total. As the power of the lens was increased, mean performance declined, although nine subjects improved with a correction. The drop in performance fell just short of statistical significance according to the Friedman analysis of variance ($X^2 = 5.58$, $p < .07$).

Six Marines were also tested with the broken circle targets at a distance of 12 m (40 ft) the nearest distance at which performance was slightly less than perfect. They identified 83% of the targets correctly with no correction, but their performance dropped to 40% with -1.5 D lenses and 31% with -2.5 D lenses. This decline in performance is significant, according to the Friedman analysis of variance ($X^2 = 9.0$, $df=2$, $p<.02$). None of the subjects performed better with the corrective lenses.

DISCUSSION

We hoped to find that providing the subjects with negative lenses would improve visual performance under white-out conditions. Although we did not know the magnitude of empty-field myopia which the individual marines exhibited, we assumed that the two powers of lenses would bracket the mean amount of correction that would be expected in young men: Leibowitz and Owens[22] have reported that the mean magnitude of empty-field myopia of college-age observers is slightly under 2 D.

But it is clear that providing the subjects with negative lenses--chosen on the basis of an optometric examination for the laboratory personnel and arbitrarily for the marines to straddle the 2 D mean--did not improve visual performance in most cases. On the average, there was a decline in performance which was statistically significant for the most sensitive test, visual acuity for the broken circles.

There are several possible reasons for the failure. The principal reason was probably the absence of white-out--the lack of a reasonable degree of uniformity in the visual field. Although we hoped that at sometime during the stay at the training center we would encounter a white-out, this did not occur. We therefore resorted to an attempt to simulate an empty visual field by placing a white piece of paper with a small hole in it before the subjects' eyes. This occluded the surrounding area with its small shrubs and boulders.

It was not certain, however, whether the effect of this procedure was equivalent to the amount of myopia produced by fitting ping-pong balls over the subjects' eyes, which produces an excellent featureless field of view. To determine the effect of our procedure in the field we have remeasured the accommodation of laboratory personnel through various peepholes similar to that used at the training center and compared it with that produced by ping-pong balls with the same size peepholes.

The state of accommodation induced by looking through holes of various sizes was compared for the ping-pong ball and the sheet of paper with four subjects. Accommodation was measured with the laser optometer as the subjects looked through holes 2, 4 and 8 mm in diameter. In addition, accommodation was measured when they wore the ping pong ball and the paper when there was no hole in either. The surround was set at a different brightness than the screen so that the hole was plainly visible to the subjects, since that had been the case in the field. No target was presented; the subjects were looking at a blank field. Table 3 gives the mean magnitudes of accommodation through the various size peepholes.

Table 3. Mean magnitude of accommodation (D) when observing through various sized apertures in ping pong balls and a sheet of paper

	Size of aperture				
	None	2 mm	4 mm	8 mm	Mean
Ball	2.02	1.56	1.89	1.89	1.84
Paper	1.28	1.06	1.03	1.27	1.19

The size of the apertures had little effect on accommodation, but there was significantly ($p < .001$) less accommodation through the paper than through the ping pong balls. It seems unquestionable, therefore, that the corrective lenses provided for the laboratory subjects were much too strong, and it is likely that they were too strong for the marines also.

There are other questions which arise under these field conditions. The subjects did not hold the peepholes in front of their eyes continuously during the experiment but only while making a given

judgment. Between judgments, they turned their backs to the target area and looked elsewhere. It is not certain, however, how long it takes empty-field myopia to develop. Heath[27] has reported that empty-field myopia tends to increase during the first three to five minutes. If so, then it is unlikely that the full extent of the myopia developed in these subjects.

Another problem is associated with the fact that there were stimuli in the field, such as shrubs and boulders, which were clearly visible if the subjects looked for them. Although it is true that when the subjects fixated on the target these extraneous stimuli were not visible, we do not know if the subjects, from time to time, looked over at these other objects. Such behavior is not inconceivable if the subject is having difficulty seeing the target: under such conditions there would be a great temptation to look elsewhere to assure oneself that one can still see something. If this did happen, then the stimuli may have been adequate to stimulate accommodation and eliminate the empty-field myopia. The deterioration in performance when wearing the corrections may show that overcorrection for the myopia is just as deleterious as undercorrection.

The question of what stimulation is sufficient to eliminate empty-field myopia has, however, never been definitely answered.[28-32] Since it is not clear what size or contrast of target is needed to stimulate accommodation, we cannot be sure what effect the extraneous stimuli had on any empty-field myopia which existed in our subjects. This variable will be studied in the laboratory before further field trials are carried out. There is little question, however, that all these problems undoubtedly played a part in the failure to demonstrate an improvement in visual performance.

SUMMARY AND CONCLUSIONS

In winter, visibility is often degraded by the particular conditions of the season. Snow-covered ground can combine with an overcast sky to produce a flat-lighted scene devoid of shadows and highlights in which it is very difficult to perceive undulations in the terrain, estimate distance, and detect subtle visual stimuli. The extreme example of poor conditions for visibility is the so-called condition of "white-out." Under this condition, observers typically become near sighted, suffer a great loss of ability to detect more distant objects which would ordinarily be seen quite easily, and soon become completely disoriented.

These experiments have tested two possible means of improving vision under such conditions: yellow goggles which are reputed to improve visual contrast under conditions of flat lighting, and lenticular corrections for the myopia which occurs when the observer is in an empty visual field.

Although yellow goggles have previously been found to produce no improvement in resolution acuity, these experiments show that they do improve the ability to perceive depressions in snow-covered terrain. Further research is needed to better specify the various conditions under which the goggles will prove useful.

The lenticular corrections did not improve vision in the conditions under which they were tested. They were not tested, however, under complete white-out conditions. Until they can be tested under such conditions, no conclusions can be drawn as to their effectiveness in relieving empty-field myopia. Further research would also be useful to specify the stimulus conditions which are sufficient to overcome the effects of white-out.

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The ability to see well deteriorates markedly under conditions of uniform visual stimulation (white-out). These conditions are frequently encountered by both the Navy and Marine Corps troups operating in winter environments. This study tested two different visual aids in an attempt to improve vision under these conditions. One of the aids, a yellow goggle, showed promise for improving the perception of depth in both low light and snowy conditions. The other, a correction for empty-field myopia (nearsightedness induced by a

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featureless visual field) did not improve vision. Further research is planned to specify more precisely the conditions in which the yellow goggles improve vision, and to investigate the reasons for the failure of the lenticular corrections to improve vision.